Space Technology Research Grants

Avionics for Hibernation and Recovery on Planetary Surfaces

Completed Technology Project (2011 - 2015)

Project Introduction

Landers and rovers endure on the Martian equator but experience avionics failures in the cryogenic temperatures of lunar nights and Martian winters. The greatest vulnerability is battery failure due to dielectric breakdown. Other components fail, and interconnects break from fatigue. The current state of practice is for planetary robots to keep their electronics above cryogenic temperatures by using radioisotope heater units (RHUs) and electrical heaters from stored energy. RHUs are costly, risky, and impossible for non-government use. Radioisotope thermoelectric generators and future sources like reactors and fuel cells might power lunar, polar, and mercurial nights but they are impractical for small missions. Small, near-term surface systems must recover after enduring cryogenic hibernation. This ambition requires freeze tolerant batteries, durable devices, and systems. Certain battery chemistries hold the prospect for tolerating cryo-freeze and freeze tolerant electronics would address temperature relevant failure mechanisms, removing the need for heating because the entire system could withstand exposure to cryogenic temperatures without damage. A power system designed around these concepts could enable planetary rovers and landers to withstand the cold of lunar, Martian, asteroidal, and mercurial nights without the aid of survival heaters or isotope power sources. This is possible by hibernating at cryogenic night temperatures and then reviving repeatedly with rising of the sun. This research proposes to develop avionics capable of hibernation and recovery from cryo-freeze. The initiative will illustrate principles by integrating and testing a solar power system including battery that survives three cycles from -170ºC to 115ºC in a thermal vacuum chamber without fault. After each hibernation and recovery phase, the power system will provide energy to a resistive load to simulate power consumption by scientific instruments, electrical motors, or a flight computer. This research is of significance to NASA because it will further the development of several key technologies presented in the NASA technology roadmap. These include photovoltaic (PV) arrays with low intensity and temperature capabilities for both outer planetary missions and surface missions where exposure to cryogenic night temperatures is anticipated, ultra-low temperature rechargeable batteries for planetary exploration, and a power system that is modular, configurable, low loss, and implements user selectable protection algorithms. An archetypal power system will be conceived, designed, analyzed, prototyped, and tested. This system will generate electricity with a multi-junction PV array, maximize collected energy through maximum power point tracking, store collected energy in a freeze tolerant battery, and detect and isolating faults. The power system will be designed to enter a state of hibernation when its temperature falls below -20ºC, and emerge from hibernation when its temperature rises above 0ºC. A test campaign will characterize the capabilities of each subsystem across a broad spectrum of thermal profiles and under vacuum. After subsystem testing, the power system will be integrated and retested as a complete unit. After the complete system has passed tests at Carnegie Mellon's facilities the system will be tested in thermal vacuum at a NASA. The findings of this

Project Image Avionics for Hibernation and Recovery on Planetary Surfaces

Table of Contents

Organizational Responsibility

Responsible Mission Directorate:

Space Technology Mission Directorate (STMD)

Responsible Program:

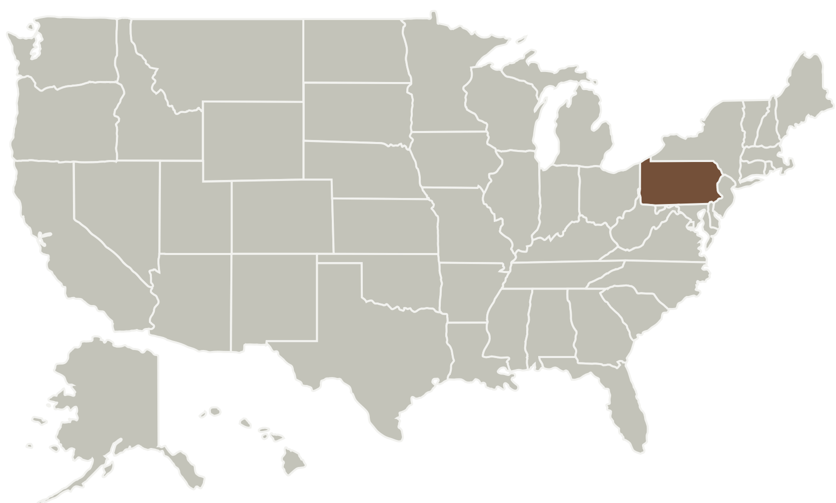
Space Technology Research Grants

research will be presented at the Lunar Superconductor Applications 2nd International Workshop (LSA). Additionally, findings will be incorporated into a lander/rover mission to endure diurnal cycles on the moon's surface.

Anticipated Benefits

This research is of significance to NASA because it will further the development of several key technologies presented in the NASA technology roadmap. These include photovoltaic (PV) arrays with low intensity and temperature capabilities for both outer planetary missions and surface missions where exposure to cryogenic night temperatures is anticipated, ultra-low temperature rechargeable batteries for planetary exploration, and a power system that is modular, configurable, low loss, and implements user selectable protection algorithms.

Primary U.S. Work Locations and Key Partners



Primary U.S. Work Locations
Pennsylvania

Project Management

Program Director:
Claudia M Meyer

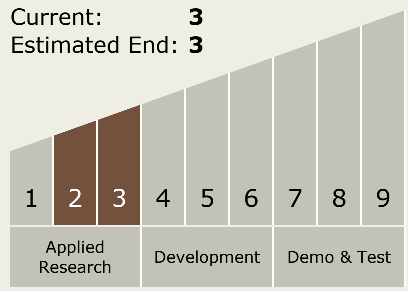
Program Manager:
Hung D Nguyen

Principal Investigator:
William Whittaker

Co-Investigator:
Ethan M Minogue

Technology Maturity (TRL)

Start: **2**
Current: **3**
Estimated End: **3**



Technology Areas

Primary:

- TX11 Software, Modeling, Simulation, and Information Processing
  └ TX11.1 Software Development, Engineering, and Integrity
    └ TX11.1.1 Tools and Methodologies for Software Design and Development

Images

4247-1363269319464.jpg
Project Image Avionics for Hibernation and Recovery on Planetary Surfaces
(https://techport.nasa.gov/image/1847)

Project Website:

https://www.nasa.gov/directorates/spacetech/home/index.html